Lean Enablers for Managing Lean Satellite Science and Technology Payload Missions

International Workshop on Lean Satellites
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Agenda

- NASA management process for determining mission and science payload* risk classification
- Examine the management implications of mission science risk classification
- Typical challenges with implementing science payloads of varying risk classifications
- The value of balancing our science and technology missions approach portfolio
- Observations/suggestions going forward

***-Science payload- Any airborne or space equipment or sensor that is not an integral part of the carrier vehicle and contributes to the science objectives. Small Satellite Missions ?**

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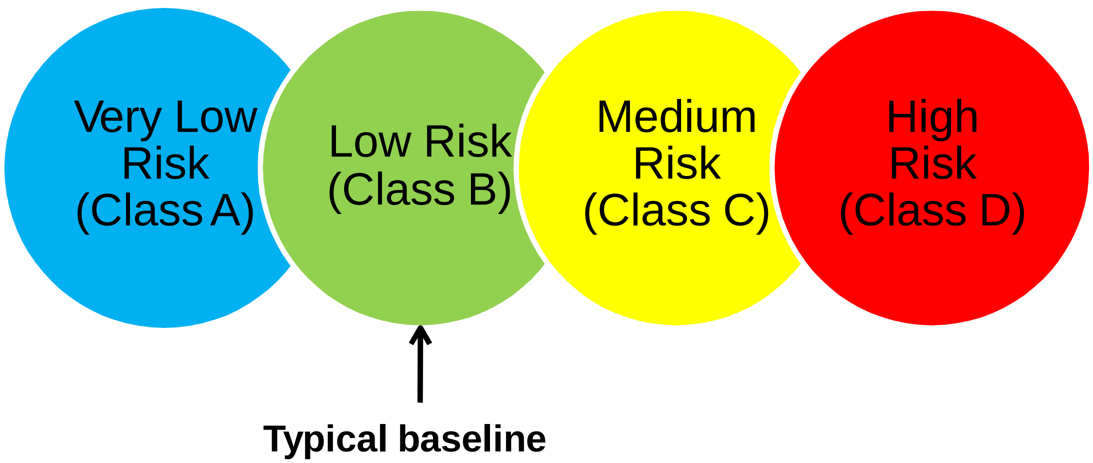
View From the Top

- In general NASA* divides all airborne/space science equipment into one of four risk classifications-



- Determining the risk classification for a particular payload is an *inexact,* iterative process
  – Classification is finalized prior to Preliminary Design Review through a combination of various NASA offices/organizations/ councils

*- NPR 8705.4, "Risk Classifications for NASA Payloads"

Risk Classification Considerations*

	Class A (Very Low Risk)	Class B (Low Risk)	Class C (Medium Risk)	Class D (High Risk)
Priority (Criticality to Agency Strategic Plan) and Acceptable Risk Level	High priority, very low (minimized) risk	High priority, low risk	Medium priority, medium risk	Low priority, high risk
National Significance	Very high	High	Medium	Low-to-medium
Complexity	Very high to high	High to medium	Medium to low	Medium to low
Mission Lifetime (Primary Baseline Mission)	Long >5yrs	Medium 2-5 yrs	Short(~3)	Short (<2 yrs)
Cost	High	High to Medium	Medium to low	Low
Launch Constraints	Critical	Medium	Few	Few to None
In-flight Maintenance	N/A	Not feasible or difficult	May be feasible	May be feasible and planned
Alternative Research Opportunities or Re-flight Opportunities	No alternative or re-flight opportunities	Few or no alternative or re-flight opportunities	Some or few alternative or re-flight opportunities	Significant alternative or re-flight opportunities
Achievement of Mission Success Criteria	All practical measures are taken to achieve minimum risk to mission success. The highest assurance standards are used.	Stringent assurance standards with only minor compromises in application to maintain a low risk to mission success.	Medium risk of not achieving mission success may be acceptable. Reduced assurance standards are permitted.	Medium or significant risk of not achieving mission success is permitted. Minimal assurance standards are permitted. 4

*-NPR 8705.4

Example- Deep Space Science Mission

	Class A (Very Low Risk)	Class B (Low Risk)	Class C (Medium Risk)	Class D (High Risk)
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Example- Earth Science Orbiter (3 yr mission)

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Example- Science Instrument for Mars Lander

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Example- Space Station Science Demo

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Risk Classification Implications

- For each of NASA's four risk classes, there are companion guidelines/requirements in each of the following areas*-

Single Point Failures	**Safety**	Maintainability
Hardware (EM, Flight, Spares)	Materials	Quality Assurance
Test program (Qual, ProtoFlight, Acceptance)	Reliability	Software (assurance)
EEE Parts	Fault Tree Analysis	**Risk Management**
Reviews	Probabilistic Risk Assessment	**Telemetry Coverage**

- With a few exceptions (noted in blue), the level of rigor and penetration required in each of these areas varies with classification, i.e. the expectations for low risk payload electronic parts are much greater than for a high risk payload

*- NPR 8705.4

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Recap- It's a Two Step Process

STEP 1

Low

Medium

Very Low

High

Designate a Risk Class

STEP 2

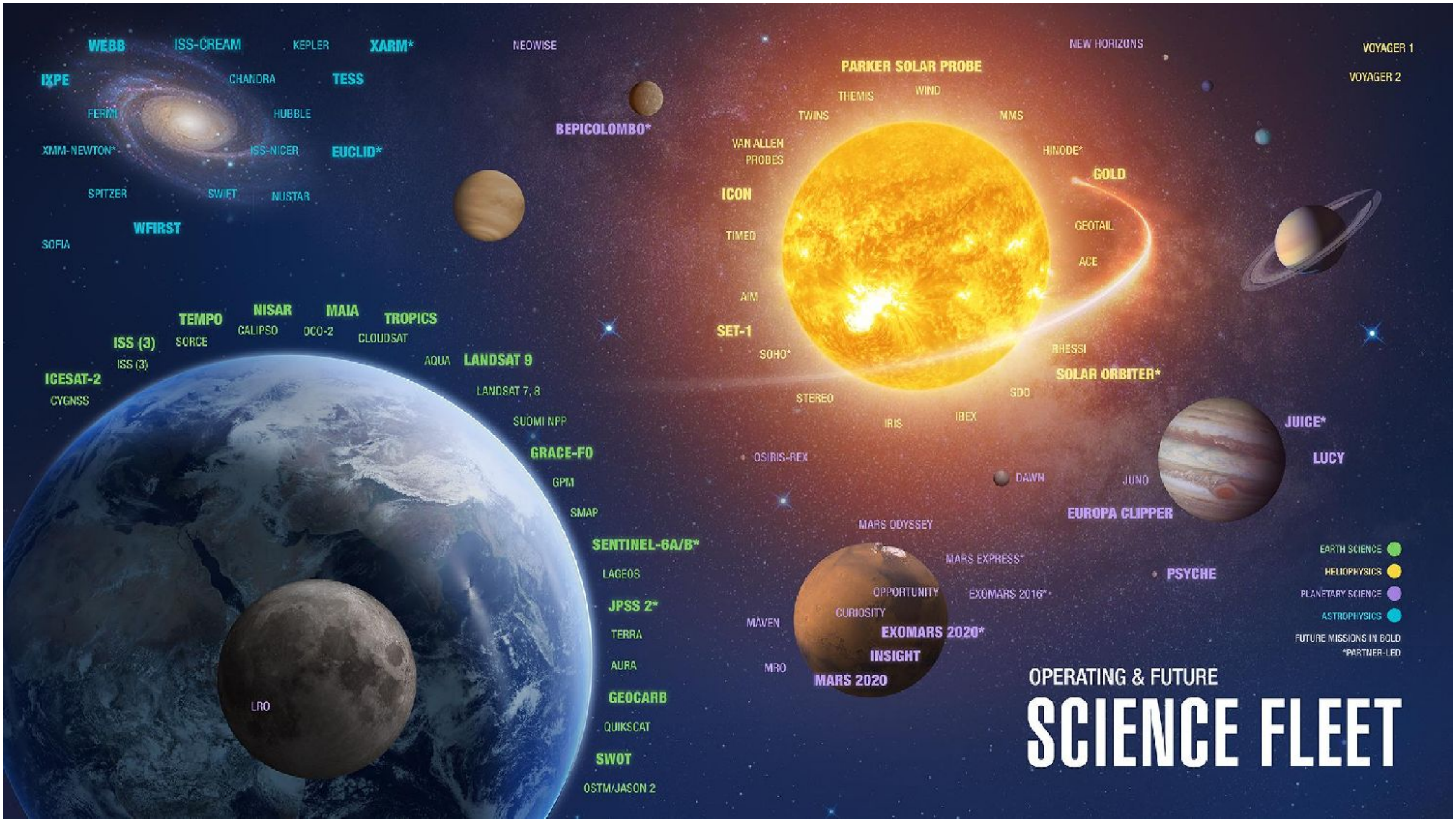
Evaluate requirements associated with the designated risk classification*

EEE Parts
- Class A- NPSL Level 1
- Class B- NPSL Level 1/2
- Class C- NPSL Level 1/2/3
- Class D- NPSL Level 1/2/3

Reliability
- Class A- FMEA, Worst Case, Parts Stress Analysis
- Class B- Box level FMEA, Worst Case, Parts Stress
- Class C- Interface FMEA, Parts Stress
- Class D- Based on safety requirements

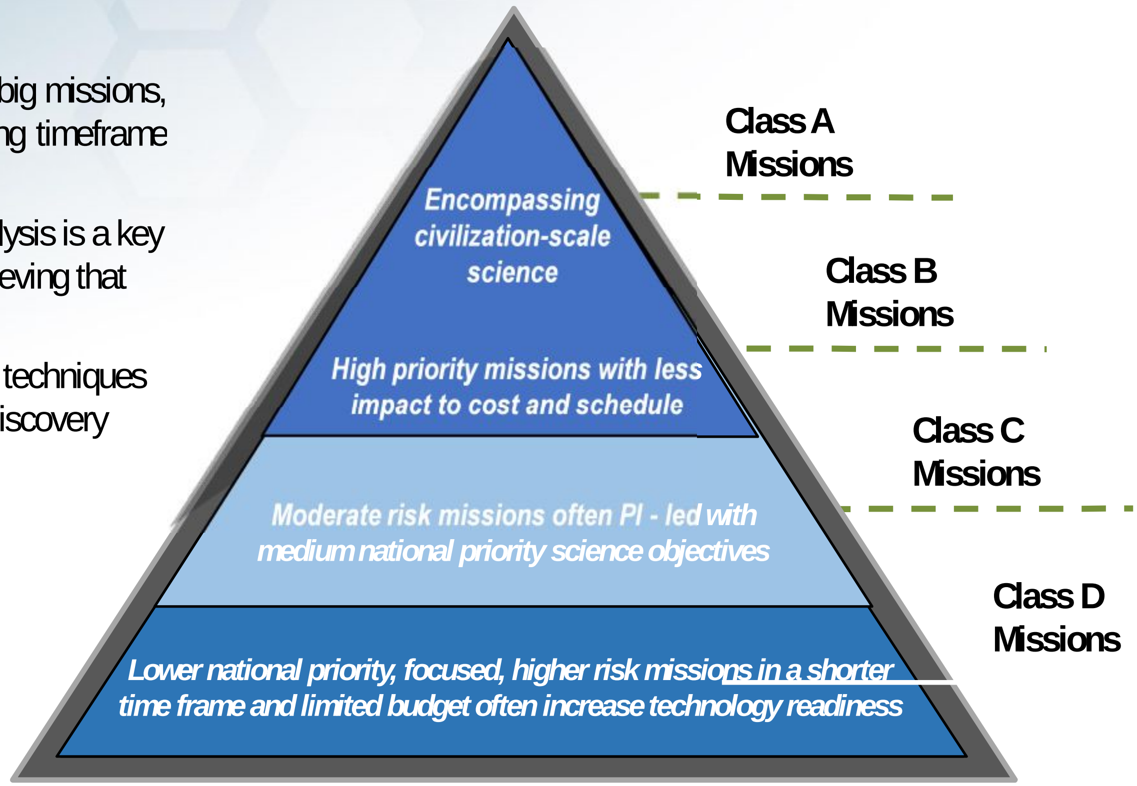
Etc
- Class A
- Class B
- Class C
- Class D

*- per NPR 8705.4

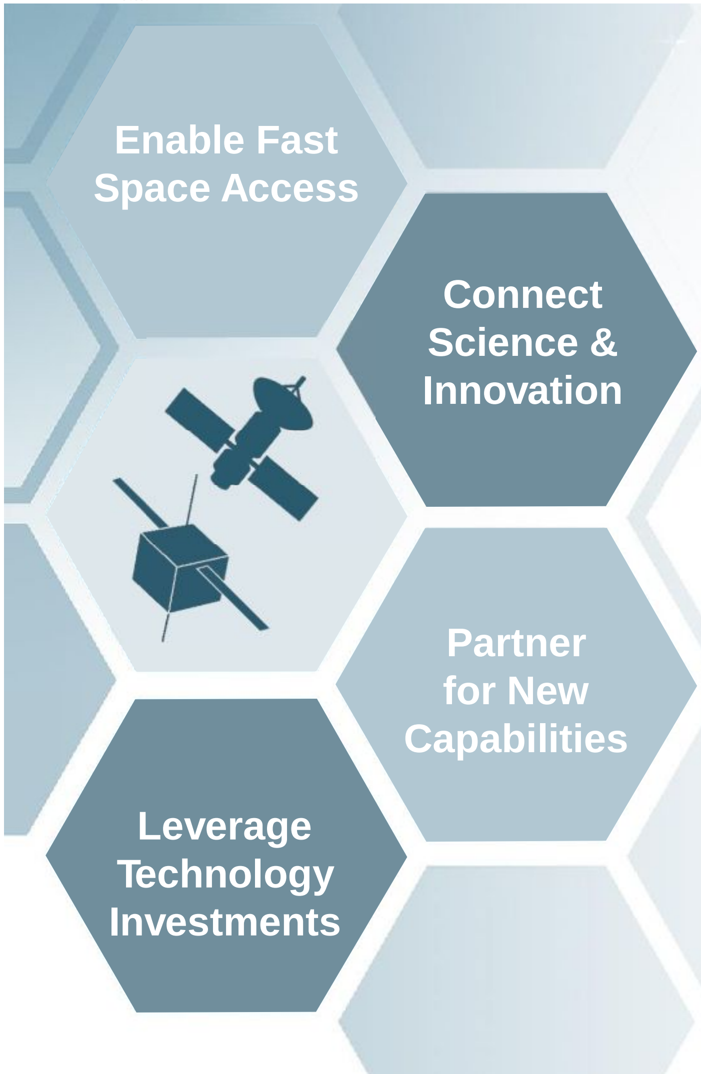

WEBB
ISS-CREAM
KEPLER
XARM*
NEOWISE
IXPE
CHANDRA
TESS
FERMI
HUBBLE
XMM-NEWTON*
ISS-NICER
EUCLID*
SPITZER
SWIFT
NUSTAR
WFIRST
SOFIA
BEPICOLOMBO*
NEW HORIZONS
VOYAGER 1
VOYAGER 2
PARKER SOLAR PROBE
THEMIS
WIND
TWINS
MMS
VAN ALLEN PROBES
HINODE*
GOLD
ICON
TIMED
GEOTAIL
ACE
AIM
SET-1
SOHO*
RHESSI
SOLAR ORBITER*
STEREO
SDO
IRIS
IBEX
TEMPO
NISAR
MAIA
TROPICS
CALIPSO
OCO-2
CLOUDSAT
ISS (3)
SORCE
ISS (3)
AQUA
LANDSAT 9
ICESAT-2
CYGNSS
LANDSAT 7, 8
SUOMI NPP
GRACE-FO
GPM
SMAP
SENTINEL-6A/B*
LAGEOS
JPSS 2*
TERRA
AURA
GEOCARB
QUIKSCAT
SWOT
OSTM/JASON 2
LRO
OSIRIS-REX
DAWN
JUNO
JUICE*
LUCY
EUROPA CLIPPER
MARS ODYSSEY
MARS EXPRESS*
PSYCHE
OPPORTUNITY
EXOMARS 2016*
CURIOSITY
MAVEN
EXOMARS 2020*
INSIGHT
MRO
MARS 2020
EARTH SCIENCE
HELIOPHYSICS
PLANETARY SCIENCE
ASTROPHYSICS
FUTURE MISSIONS IN BOLD
*PARTNER-LED
OPERATING & FUTURE
SCIENCE FLEET

The Value of a Balanced Portfolio

- Importance of the big missions, but recognizing long timeframe to achieve results
- Research and Analysis is a key component of achieving that balance
- Employ innovative techniques to grow scientific discovery



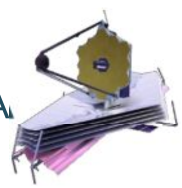
Class D Strategy



Innovative Techniques to Inspire Learners

- **Expand** science programs to take advantage of Class D and small satellite rapid innovation to achieve breakthrough science
- **Enable** fast access to space for focused science measurements that fill a critical gap between large flight projects
- **Leverage** technology investments to further improve potential of science instruments
- **Partner** with international agencies and commercial entities to acquire new capabilities of small satellite platforms

CLASS A



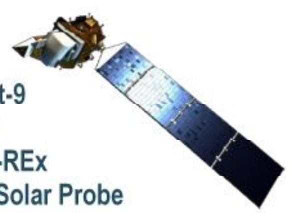
- High priority
- Very high significance
- High complexity
- Long mission lifetime
- High cost
- Critical launch constraints
- No re-flight opportunities

Cassini
Webb
Europa Clipper
Mars 2020

CLASS B

- High priority
- High significance
- High to medium complexity
- Medium mission lifetime
- High to medium cost
- Medium launch constraints

Juno
Landsat-9
InSight
OSIRIS-REx
Parker Solar Probe



CLASS C

- Medium priority
- Medium significance
- Medium to low complexity
- Short mission lifetime
- Medium to low cost
- Few launch constraints

MMS
ICESat-2
TESS
GRACE Follow-on
ICON

CLASS D

- Low priority
- Low to medium significance
- Short mission lifetime
- Medium / low complexity
- Low cost
- Few to no launch constraints
- Re-flight opportunities

CYGNSS
NICER
TROPICS
GeoCarb
ECOSTRESS

Class D Strategy Implementation

Accepting higher risk for scientific gain by implementing a tailored, streamlined classification approach

SMD Implementation
Reviews

- Lifecycle Reviews conducted by project implementing institution
- Only two NASA required reviews during the Project development lifecycle
- Delegated Decision Authority
- Review Teams as small as practicable

SMD Implementation
Documentation

- Only final documentation submitted to NASA HQs for approval; no preliminary documentation
- Final Project documentation approved at the Division Director level
- Merging documentation encouraged
- Tailoring Mission Assurance Requirements (MAR), with a goal to reduce documentation deliverables and reviews

SMD Implementation
Performance Management

- Formal Earned Value Management (EVM) and a certified EVM system is not required
- NASA will develop only one NASA ICE/ISE
- KDP-C decision will be made based on 60% confidence levels, and not based on the usual 70%
- 7 Basic principles apply: Per Robert Lightfoot memo 9/26/14, AO website: https://soma.larc.nasa.gov/standardao/

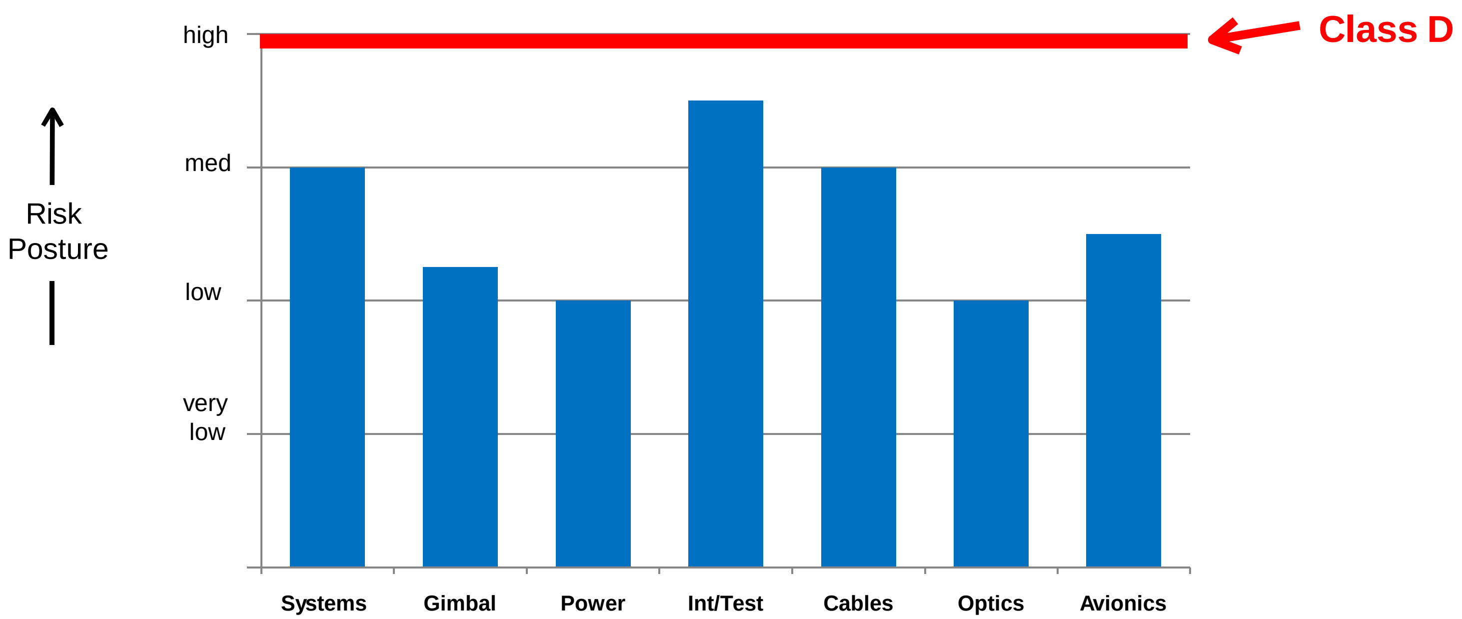
IMPLEMENTATION CHALLENGES

Main Challenges

- At NASA, there are generally two challenges in dealing with NASA's multiple science payload risk classifications-
  1) Science payloads with a <u>lower</u> risk posture than the traditional NASA "low risk" Institutional baseline- i.e., "very low" risk missions, for example Lean Missions ?
     - Meeting these guidelines requires unique add-ons to the way NASA typically performs work
       – Impact of SIX SIGMA approach is usually largely programmatic- increases in cost and cycle time (full qualification & acceptance test programs, separate prototype and flight models, etc)
  2) Science payloads that adopt a <u>higher</u> risk posture than the NASA "low risk" Institutional baseline- "medium/high" risk missions
     - In our experience, more effort (than expected) is required to actually execute a science payload mission with less than traditional rigor and penetration
  3) Opportunities for use of Lean SIX SIGMA approaches

Medium/High Risk Payload Challenges

- The willingness to assume "additional" risk, versus normal practice(s), is typically uneven throughout an organization



Recent JPL Class D (high risk) Mission at PDR

- "Medium/high risk is OK in other areas, but not mine"

Medium/High Risk Science Payload Challenges

- In some areas, there is no clear line of demarcation (based on current guidelines) between various risk postures- which leads to differences in interpretation
  - Examples

Spares*

Low Risk	Medium Risk	High Risk
"..Spare hardware as needed to avoid major program impact."	"..Limited flight spare hardware (for long lead flight units)."	"..Limited engineering model and flight spare hardware."

Quality Assurance*

Low Risk	Medium Risk	High Risk
"… moderate surveillance"	"… tailored surveillance"	"… Based on applicable safety requirements"

*- NPR 8705.4

Medium/High Risk Payload Challenges

- There are corollary, unstated risks which need to be understood and communicated
  - Example
    - Medium/high risk payload guidelines allow the use of NASA Parts Selection List (NPSL) Quality Level 3 parts
      - Unstated risk-The radiation tolerance/hardness of NPSL Level 3 parts is typically not easily quantifiable
        - » Little or no test data
        - » Lot variability
        - » Use of off-shore suppliers
      - Result- Projects choose between painful options, including-
        - » Accept risk of a radiation-induced unrecoverable event (with an undefined likelihood of occurrence)
        - » Spend funds to characterize the parts (typically considered an out-of-scope task)

High Risk Payload Challenges

- During implementation of high risk payloads, there is a tendency to stray from the guidelines and expand the boundaries of what is acceptable. Common signs of this trend include-
  - Best practices and lessons learned are overlooked/ omitted
  - Documentation rigor suffers
  - Success criteria becomes less well defined, leading to potential miscommunication/misunderstandings with the customer/sponsor

- Implementation of high risk payloads requires specialized, unique training.
  - For many, this seems to be counterintuitive
  - It is hard to clearly define the “dos” and “don’ts” for high risk baselines

High Risk Payload Challenges

- The human-rated safety requirements for International Space Station (ISS) payloads restrict “flexibility”-

	High Risk Approach*	Additional ISS Safety-related Requirement
Single Point Failures	“…single string approaches may be used.”	Critical SPFs may be permitted if there are no safety impacts (per NSTS 1700.7B)
Materials	“..based on applicable safety requirements”	All materials shall be verified as specified in ICDs, NSTS 14046 and NSTS 1700.7B/ SSP 50021
Test Program	“..only for verification of safety compliance and interface compatibility”	Payloads will be required to be proven structurally safe and compatible with the ISS for all expected flight environments. This process will include verification of payload structural strength and life integrity as well as strength verification for selected materials.

- These additional requirements complicate the costing/planning process for technology development of science payloads, which are typically viewed as high risk

*- NPR 8705.4

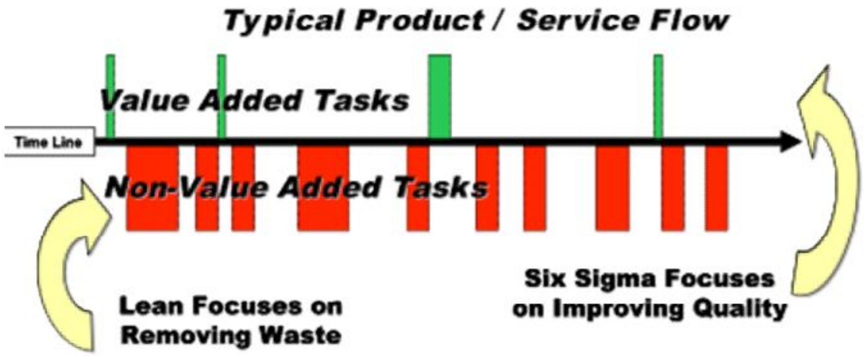
Combining Lean and Six Sigma for Some Science Payloads

Lean and Six Sigma are widely used in industry as continuous improvement best practices

They can also be very **complementary** in nature and, if performed properly, can produce unprecedented results

Lean focuses on eliminating non-value added activities in a process and Six Sigma focuses on reducing variation from the remaining value-added steps

Lean provides speed ensuring products and services flow without interruption while Six Sigma ensures that critical product / service characteristics are completed correctly the very first time we do them.



Summary

- The advantages of early identification of an acceptable project risk posture for a science payload include-
  - Serves to baseline expectations and enhances communication among participants, as well as with customers and suppliers
  - Reduces the amount of time/expense required to justify deviations to normal practices

- Medium/high risk implementation approaches tend to move people out of their comfort zone
  - In our experience, more effort (than expected) is required to actually execute a science payload with less than traditional rigor and penetration. However an appropriately balanced approach that combines Six Sigma with lean system engineering, lean management, lean science, lean operations show promise for future science missions and use of Lean Satellites

- When working on high risk man space flight projects strict adherence to guidelines, training and practiced lessons learned are (still) keys to success

QUESTIONS PLEASE ?

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References

Presentations;
Kenneth W. Ledbetter NASA, Science Mission Directorate Implementation of Spacecraft Risk Classifications;

Kim Plourde Caltech , Challenges in Implementing Medium & High Risk NASA Payloads and

Thomas Zurbuchen and Gregory Robinson, Science Mission Directorate Class D Strategy

BACK-UP

Definitions

- Payload- Any airborne or space equipment or material that is not an integral part of the carrier vehicle (i.e. not part of the carrier aircraft, balloon, sounding rocket, expendable or recoverable launch vehicle). Included are items such as free-flying automated spacecraft, Space Shuttle payloads, Space Station payloads, Expendable Launch Vehicle payloads, flight hardware and instruments designed to conduct experiments, and payload support equipment

- NASA payload- Any payload for which NASA has design, development, test or operations responsibility

Example Missions

Class A	Class B	Class C	Class D
HST, Cassini, JWST	MER, MRO, Discovery payloads, ISS Facility Class Payloads, attached ISS Payloads	ESSP, Explorer Payloads, MIDEX, ISS complex subrack payloads	SPARTAN, GAS Can, technology demonstrators, simple ISS, express middeck and subrack payloads, SMEX